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EXAMINER	
SIANGCHIN, KEVIN	
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Please find below and/or attached an Office communication concerning this application or proceeding.

PTO-90C (Rev. 10/03)

Office Action Summary	Application No.	Applicant(s)
	09/847,011	MATSUMOTO, YUKINORI
	Examiner	Art Unit
	Kevin Siangchin	2623

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If the period for reply specified above is less than thirty (30) days, a reply within the statutory minimum of thirty (30) days will be considered timely.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *10 June 2004*.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) *1-69* is/are pending in the application.

4a) Of the above claim(s) *11,12,23,24 and 35-37* is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) *1-10, 13-22, 25-34, 38-69* is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☒ The specification is objected to by the Examiner.

10)☒ The drawing(s) filed on *10 May 2001* is/are: a)☐ accepted or b)☒ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)

2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)

3) ☒ Information Disclosure Statement(s) (PTO-1449 or PTO/SB/08) Paper No(s)/Mail Date 2/______.

4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .

5) ☐ Notice of Informal Patent Application (PTO-152)

6) ☐ Other: _____.

Detailed Action

Election/Restrictions

1. Restriction to one of the following inventions is required under 35 U.S.C. 121:

   I. Claims 1-10, 13-22, 25-34, 38-69, drawn to three dimensional modeling apparatuses, methods, and/or stored computer programs, classified in class 382, subclass 154.

   II. Claims 11-12, 23-24, and 35-37, respectively drawn to three dimensional shape data recording apparatuses, methods, and/or stored computer programs for recording three dimensional shape data of a three dimensional object, classified in class 382, subclass 154.

2. Inventions I and II are related as subcombinations disclosed as usable together in a single combination. The subcombinations are distinct from each other if they are shown to be separately usable. In the instant case, invention II has separate utility such as recording 3D shape data, which may not, in and of itself, correspond to the data of a 3D model of an object (e.g. 3D temperature gradient of an object can represent 3D shape data), or may correspond to a 3D model generated by a modeling process, apparatus, and/or computer program other than invention I (e.g. CAD or CSG models). See MPEP § 806.05(d).

3. Because these inventions are distinct for the reasons given above and have acquired a separate status in the art because of their recognized divergent subject matter, restriction for examination purposes as indicated is proper.

<u>Election By Telephone</u>

4. During a telephone conversation with Mr. Roger R. Wise on June 10, 2004 a provisional election was made with traverse to prosecute the invention of invention I, Claims 1-10, 13-22, 25-34, 38-69. Affirmation of this election must be made by applicant in replying to this Office action. Claims 11-12, 23-24, and 35-37 are withdrawn from further consideration by the examiner, 37 CFR 1.142(b), as being drawn to a non-elected invention.

Drawings

Objections

5. The drawings are objected to because of the following. According to page 29, lines 15-22 of the Applicant's disclosure:

> As shown in FIG. 6, tables each corresponding to one of the variables X, Y, Z, α, β, and γ are prepared and all the values of X, Y, Z, α, β, and γ obtained for all the combinations are polled in the table. The value that forms a peak in each table is considered as the valid value. A point in FIG. 6 pointed by an arrow in the upward direction represents the valid value for that variable.

Fig. 6 does not depict tables. Furthermore, no indication is given in Fig. 6 as to what the ordinate of the graphs depicted in Fig. 6 corresponds to. Illustration and labeling of an ordinate axis would clarify Fig. 6. See also the corresponding discussion below with regard to the Applicant's specification.

6. According to page 32, lines 20-25 of the Applicant's disclosure:

> ...the light portion of pattern A (shown as (A) in FIG. 10) is (1111) and the dark portion of pattern A is (0000), and the overall pattern can be represented by 8 bits, (11110000). Similarly, pattern B (shown as (B) in FIG. 10) is (11001100) and pattern C (shown as (C) in FIG. 10) is (10101010).

This is clearly not depicted in Fig. 10. In Fig. 10, the dark portions of the depicted patterns correspond to codes of all 1's, whereas the light portions correspond to codes of all 0's. See also the corresponding discussion below with regard to the Applicant's specification. A proposed drawing correction or corrected drawings are required in reply to the Office action to avoid abandonment of the application. The objection to the drawings will not be held in abeyance.

7. Figures 9 and 15 should be designated by a legend such as -- *Prior Art* -- because only that which is old is illustrated. See MPEP § 608.02(g). Corrected drawing sheets are required in reply to the Office action to avoid abandonment of the application. The replacement sheet(s) should be labeled "Replacement Sheet" in the page header (as per 37 CFR 1.84(c)) so as not to obstruct any portion of the drawing figures. If the changes are not accepted by the examiner, the applicant will be notified and informed of any required corrective action in the next Office action. The objection to the drawings will not be held in abeyance.

Specification

Objections

8. The disclosure is objected to because of the following informalities.

a. The equation 1 referred to in page 28, lines 27 to page 29, lines 5 is not given.

b. According to page 29, lines 15-22 of the Applicant's disclosure:

> As shown in FIG. 6, tables each corresponding to one of the variables X, Y, Z, α, β, and γ are prepared and all the values of X, Y, Z, α, β, and γ obtained for all the combinations are polled in the table. The value that forms a peak in each table is considered as the valid value. A point in FIG. 6 pointed by an arrow in the upward direction represents the valid value for that variable.

No tables are shown in Fig. 6. Instead, Fig. 6 depicts graphs, plots, or the like. Referring to these as such would be more descriptive of what is depicted in Fig. 6. Moreover, it is not clear from the specification or from Fig. 6 what exactly is being depicted in Fig. 6. Specifically, the graphs of Fig. 6 show individual relationships between the variables X, Y, Z, α, β, γ and some dependant variable (the value of which extends along the ordinate direction). However, it is unclear from the Applicant's disclosure what that dependant variable is.

Note that changes made to the specification to rectify these issues would obviate the need for the drawing corrections of Fig. 6 suggested above.

c. On page 31, lines 26 of the Applicant's disclosure, the Applicant refers to a *gypsum block*. It is unclear from the Applicant's disclosure as to what a gypsum block is. The Applicant's usage of the word gypsum[1], is not consistent with anything found in the field of computer graphics and image processing, nor can its meaning, and hence the meaning of a gypsum block, be gleaned from the Applicant's specification.

d. On page 32, line 7 of the Applicant's disclosure, the Applicant refers to "such a *convex* shape". The word convex should be replaced with the word *concave* in order to be

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1 Gypsum is used to make plaster.

consistent with the rest of the disclosure (e.g. the inside of a cup – page 32, line 5 of the Applicant's disclosure – is concave not convex). Similar errors occur on page 36, lines 18, 22 and 26 and page 50, line 2 of the Applicant's disclosure.

e. According to page 32, lines 20-25 of the Applicant's disclosure:

> ...the light portion of pattern A (shown as (A) in FIG. 10) is (1111) and the dark portion of pattern A is (0000), and the overall pattern can be represented by 8 bits, (11110000). Similarly, pattern B (shown as (B) in FIG. 10) is (11001100) and pattern C (shown as (C) in FIG. 10) is (10101010).

This is clearly not depicted in Fig. 10. In Fig. 10, the dark portions of the depicted patterns correspond to codes of all 1's, whereas the light portions correspond to codes of all 0's. Changing the specification to indicate this would rectify this matter and obviate the need for any of the proposed corrections to Fig. 10, discussed above.

f. It is suggested that the word *slashes* on page 39, lines 8 of the Applicant's disclosure, be changed to *cross-hatching* or *cross-hatched region*.

g. On page 39, lines 22 of the Applicant's disclosure, (Date recording) should be changed to (Data Recording).

h. On page 40, line 1 of the Applicant's disclosure, the word Foe should be changed to For.

i. Please consider revising the sentence on page 40, lines 20-25 of the Applicant's disclosure. This sentence, as presently written, is grammatically awkward to the point that it is unclear.

j. It is suggested that (Others) on page 41, line 23 of the Applicant's disclosure, be changed to (Miscellaneous), or something similar.

k. A period (.) is missing on page 47, line 8 of the Applicant's disclosure.

Appropriate correction is required.

Claims

Objections

9. Claims 42-44, 46, 48, 58-59, and 62-64 are objected to because of the following informalities. Claim 42-44, 46, 48, 58-59, and 62-64 recite the limitation "the images" or "said input images". There is insufficient antecedent basis for this limitation in the claim. For example, claim 44 recites, "said image input means performs image input where *the images* are captured at least two different points at different locations" and "color or density changes is performed between *input images*". However, parent claim 3, recites, "image input means for inputting *an image* of said three dimensional object". That is, claim 3 indicates input of a single image, whereas, claim 44 implies the input of at least one image. To rectify this, the Applicant could change the language of the claims, in this case claim 3, to indicate that image input is of at least one image, as opposed to *an* image. Changes should be made to those claims of the set 42-44, 46, 48, 58-59, and 62-64 that are independent. For the dependant claims (e.g. claim 44) of the set 42-44, 46, 48, 58-59, and 62-64, changes should be made to the claims upon which these depend. (e.g. claim 3). Appropriate correction is required.

10. Claims 5 and 17 are objected to because of the following informalities. The word *exits* should be replaced with the word *exists*. Appropriate action is required.

Rejections Under 35 U.S.C. § 112(2)

11. The following is a quotation of the second paragraph of 35 U.S.C. 112:

> The specification shall conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the applicant regards as his invention.

12. Claims 49 and 64 rejected under 35 U.S.C. 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which applicant regards as the invention.

13. These claims refer to *divided regions* of the input images. It is not clear to what divided regions of the input images the Applicant is referring. In accordance with their respective parent claims, divided regions of the input images, in claims 49 and 64 will be interpreted as portions where color density changes. This is consistent with the description found in the Applicant's specification of divided regions or strips. See the first paragraph on page 3 and the section, Detailed Shape Calculation Step Using Space Coding Method of the Applicant's specification.

<u>Rejections Under 35 U.S.C. § 112(1)</u>

14. The following is a quotation of the first paragraph of 35 U.S.C. 112:

> The specification shall contain a written description of the invention, and of the manner and process of making and using it, in such full, clear, concise, and exact terms as to enable any person skilled in the art to which it pertains, or with which it is most nearly connected, to make and use the same and shall set forth the best mode contemplated by the inventor of carrying out his invention.

15. Claims 52 and 65 are rejected under 35 U.S.C. 112, first paragraph, as failing to comply with the enablement requirement. The claim(s) contains subject matter which was not described in the specification in such a way as to enable one skilled in the art to which it pertains, or with which it is most nearly connected, to make and/or use the invention.

16. Claims 52 and 65 propose an apparatus and method, respectively, that include *at least two* three-dimensional shape inputting means or steps. The 3D modeling methods and apparatuses of the Applicant's specification, on the other hand, consist of *at most* two 3D shape inputting means or steps. As such, the Applicant's specification does not provide adequate support for the subject matter claimed in claims 52 and 65.

<u>Rejections Under 35 U.S.C. § 102(b)</u>

17. The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

> (b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.

18. Claims 52, 65-66 and 68-69 are rejected under 35 U.S.C. 102(b) as being anticipated by Niem ("Error Analysis for Silhouette-Based 3D Shape Estimation from Multiple Views", WSNHC3DI 1997).

19. *The following is in regard to Claim 65.* Niem discloses a robust approach for the automatic 3D reconstruction of an object, from multiple camera views, using a *shape-from-silhouette* (SFS) technique (Niem page 1, left column, last paragraph). Niem further suggests extending this technique by incorporating a *Structured Light* (SL) methodology to accommodate the concave surfaces of the observed object (Niem, page 1, right column, item (i)). This extended method involves:

(65.a.) Two three-dimensional shape inputting steps – e.g. a rough shape (SFS) input step and a detailed shape (SL) step – of obtaining the three dimensional shape of the three dimensional object. See, for example, the discussion below regarding claim 13. These steps (i.e. SFS and SL steps) have different accuracy in representing 3D objects.

(65.b.) Capturing a 3D shape from multiple view points about the object. (e.g. by changing the position of moving the camera). See, for example, Niem Fig. 1(b).

It has thus been shown that this method of Niem conforms to modeling method set forth in claim 65. Therefore, the method obtained by extending an SFS method to include an SL method, as per Niem's teachings, anticipates the modeling method set forth in claim 65.

20. *The following is in regard to Claim 52.* Claims 52 recites substantially the same limitations as claim 65. (This claim proposes an apparatus implementing the method of claim 65). Therefore, with regard to claims 52, remarks analogous to those presented above with regard to claim 65 are applicable.

21. *The following is in regard to Claim 68.* Niem discloses a robust approach for the automatic 3D reconstruction of an object, from multiple camera views, using a *shape-from-silhouette* (SFS) technique (Niem page 1, left column, last paragraph). Niem further suggests extending this technique by incorporating a *Structured Light* (SL) methodology to accommodate the concave surfaces of the observed object (Niem, page 1, right column, item (i)). This extended method involves:

(68.a.) Obtaining a rough shape information (i.e. an SFS representation) of the three dimensional object.

(68.b.) Obtaining a detailed shape information (i.e. an SL representation) of the three dimensional object.

(68.c) Generating the three dimensional shape data of said three dimensional object based on the rough shape information and the detailed shape information.

See Niem page 1, left column, last paragraph to right column, item (i). It has thus been shown that the method of Niem conforms to modeling method set forth in claim 68. Therefore, the method, obtained by extending an SFS method to include an SL method, as per Niem's teachings, anticipates the modeling method set forth in claim 68.

22. *The following is in regard to Claims 66 and 69.* Claims 66 and 69 recite substantially the same limitations as claim 68. (These claims respectively propose an apparatus and stored computer program implementing the method of claim 68). Therefore, with regard to claims 66 and 69, remarks analogous to those presented above with regard to claim 68 are applicable.

Rejections Under 35 U.S.C. § 103(a)

23. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

24. Claims 1-4, 7, 10, 13-16, 19, 22, 25-28, 31, 34, 38-49, and 54-62 are rejected under 35 U.S.C. 103(a) as being unpatentable over Niem ("Error Analysis for Silhouette-Based 3D Shape Estimation from Multiple Views", WSNHC3DI 1997), in view of Batlle, et al. ("Recent Progress in Coded Structure Light As a Technique to Solve the Correspondence Problem: A Survey", Pattern Recognition, Vol. 31, 1998).

25. *The following is in regard to Claim 13.* Niem discloses a robust approach for the automatic 3D reconstruction of an object, from multiple camera views, using a *shape-from-silhouette* (SFS) technique (Niem page 1, left column, last paragraph). Niem further suggests extending this technique by

incorporating a *Structured Light* (SL) methodology to accommodate the concave surfaces of the observed object (Niem, page 1, right column, item (i)). This extended method involves:

(13.b.) Inputting (i.e. capturing) an image(s) of the three dimensional object (e.g. input images – Niem page 1, left column, last paragraph). See, for example, Niem Fig. 1(b).

(13.c.) Calculating a shape (e.g. a silhouette or the bounding volume corresponding to obtained 3D information) from the captured image(s). See Niem page 1, right column, last paragraph.

(13.e.) Generating three dimensional shape data (e.g. the bounding volume) of the three dimensional object based on the shape. See Niem page 1, right column, last paragraph.

While the step of (13.a) projecting pattern light onto a three dimensional object is critical to SL methods, and, therefore, inherent to Niem's suggested extension of the aforementioned SFS method, Niem does not expressly demonstrate this step. SL methods also include the step of (13.d) calculating a shape from captured images, namely images of the projected pattern. Again, while this step would be inherent to the extended SFS of Niem, it is not explicitly shown by Niem.

26. Batlle et al. disclose numerous *Structured-Light* methods to obtain 3D information to be used in the construction of 3D surfaces (presumably of objects – Batlle et al. Abstract). Generally speaking, Structured-Light methods involve:

(13.a.) Projecting pattern light onto a three dimensional object (i.e. "projecting a given pattern on the measuring surfaces" – Batlle et al. Abstract, lines 5-6).

(13.b.) Inputting (i.e. capturing) an image(s) of the three dimensional object (Batlle et al. page 965, left column, lines 5-6).

(13.d.) Calculating a shape (i.e. either the 2D deformed pattern projected on the *Grabbed Image* [see Batlle et al. Fig. 2] plane, or the shape corresponding to obtained 3D information) from the captured image(s) (Batlle et al. page 965, left column, lines 6-10).

(13.e.) Generating three dimensional shape data of the three dimensional object based on the shape. See Batlle et al. page 965, left column, lines 6-10 and Batlle et al. sections 4.1 and 4.3.

27. It is known that a silhouette-based representation of a 3D object does not accurately represent, or fails altogether, to represent concave surfaces of the object (Niem page 1, right column, item (–)), whereas, Structured-Light (SL) methods can accommodate such surfaces. In this manner, one can consider the silhouette-based representation (obtained by above step (13.c) of Niem) of an object a *rough shape* estimation of the object, relative to the representation obtained via the SL method (step (13.d) of Batlle et al.). Conversely, one can consider the representation obtained via the SL method a *detailed shape* estimation of the object, relative to a silhouette-based representation. Therefore, Niem suggests (Niem, page 1, right column, item (i)) calculating both a rough shape (i.e. silhouette-based model) and detailed shape (e.g. SL model such as those described by Batlle et al.), and using those shapes to generate three dimensional shape data of a three dimensional object.

28. The teachings of Niem and Batlle et al. are combinable because they are analogous art. Specifically, the teachings of Niem and Batlle et al. are both directed toward the construction of a 3D model of an object from multiple views. Moreover, Niem provides an explicit suggestion of combinability (see above). Therefore, it would have been obvious to one of ordinary skill in the art, at the time of the applicant's claimed invention, to combine an SFS reconstruction method, in the manner suggested by Niem, with an SL method to obtain an accurate 3D representation of an object. The motivation to do so would have been to accurately represent surface concavities of the object that may otherwise have been missed by using an SFS technique alone. Extending an SFS method by combining it with a SL, in the manner discussed above, yields a three dimensional modeling method that conforms to that which is set forth in claim 13.

29. *The following is in regard to Claims 1 and 25.* Claims 1 and 25 recite substantially the same limitations as claim 13. (These claims respectively propose an apparatus and stored computer program implementing the method of claim 13). Therefore, with regard to claims 1 and 25, remarks analogous to those presented above with regard to claim 13 are applicable.

30. *The following is in regard to Claims 2, 14, and 26.* Note that these claims deviate from claims 1, 13, and 25, respectively, only in that the aforementioned rough shape is input or captured, as opposed to being calculated. This does not introduce anything significant over claims 1, 13 and 25, respectively, since the calculated rough shape data may just as well be regarded as input data. In this way, claims 2 , 14 and 26

can be regarded as reciting substantially the same limitations as claim 1, 13, and 25, respectively. Therefore, with regard to claims 2, 14 and 26, remarks analogous to those presented above with regard to claim 1, 13, and 25 are respectively applicable.

31. *The following is in regard to Claim 19.* As shown above, the teachings of Niem and Batlle et al., when combined in manner discussed above, adequately satisfy the limitations of claim 13. Inherent to the step of calculating the detailed shape (i.e. the SL reconstruction), is acquiring a plurality of object surface location candidates from the input image. Since the SL method (step (13.d) above) is used to refine the SFS model (step (13.c) above), one can reasonably consider all points on an within the SFS model (i.e. the rough 3D shape) as location candidates. This, in turn, implies that points in the input image(s) that lie within silhouettes of the object can represent location candidates, from which the detailed shape can be derived. Moreover, since the depth of all points in the captured image(s) is calculated, every point within the captured image could also be regarded as location candidates. In this way, extending an SFS method by combining it with a SL, in the manner discussed above, yields a three dimensional modeling method that conforms to that which is set forth in claim 19.

32. *The following is in regard to Claim 7 and 31.* Claims 7 and 31 recite substantially the same limitations as claim 19. (These claims respectively propose an apparatus and stored computer program implementing the method of claim 19). Therefore, with regard to claims 7 and 31, remarks analogous to those presented above with regard to claim 19 are applicable.

33. *The following is in regard to Claim 22.* As shown above, the teachings of Niem and Batlle et al., when combined in manner discussed above, adequately satisfy the limitations of claim 13. It was also discussed above that the SFS (shape-from-silhouette) method is used to derive the rough shape of the reconstruction proposed by Niem. The SFS method uses silhouettes of the object to obtain a 3D model of that object. See Fig. 1(b) of Niem. Therefore, extending an SFS method by combining it with a SL, in the manner discussed above, yields a three dimensional modeling method that conforms to that which is set forth in claim 22.

34. *The following is in regard to 10 and 34.* Claims 10 and 34 recite substantially the same limitations as claim 22. (These claims respectively propose an apparatus and stored computer program implementing

the method of claim 22). Therefore, with regard to claims 10 and 34, remarks analogous to those presented above with regard to claim 22 are applicable.

35. *The following is in regard to Claim 15.* Niem discloses a robust approach for the automatic 3D reconstruction of an object, from multiple camera views, using a *shape-from-silhouette* (SFS) technique (Niem page 1, left column, last paragraph). Niem further suggests extending this technique by incorporating a *Structured Light* (SL) methodology to accommodate the concave surfaces of the observed object (Niem, page 1, right column, item (i)). This extended method involves:

(15.a_1) Inputting (i.e. capturing) an image(s) of the three dimensional object (e.g. input images – Niem page 1, left column, last paragraph), said image(s) being obtained by projecting light (i.e. illuminating) the three dimensional object. See, for example, Niem Fig. 1(b).

(15.b.) Calculating a shape (e.g. a silhouette or the or the bounding volume corresponding to obtained 3D information) from the captured image(s). See Niem page 1, right column, last paragraph.

(15.d.) Generating three dimensional shape data (e.g. the bounding volume) of the three dimensional object based on the shape. See Niem page 1, right column, last paragraph.

SL methods also include the step of (15.c) calculating a shape from captured images, namely images of the projected pattern. Again, while this step would be inherent to the extended SFS of Niem, it is not explicitly shown by Niem. Lastly, Niem does not explicitly show that the input image(s) be obtained by projecting *pattern* light onto said three dimensional image(s) (though, as will be discussed, below this aspect would be implicit to a combination of the SFS and SL methods).

36. Batlle et al. disclose numerous *Structured-Light* methods to obtain 3D information to be used in the construction of 3D surfaces (presumably of objects – Batlle et al. Abstract). Generally speaking, Structured-Light methods involve:

(15.a_2) Inputting (i.e. capturing) an image(s) of the three dimensional object, said image(s) obtained by projecting pattern light onto the three dimensional object (i.e. "projecting a given pattern on the measuring surfaces" and "imag[ing] the illuminated scene" – Batlle

et al. Abstract, lines 4-6).

(15.c.) Calculating a shape (i.e. either the 2D deformed pattern projected on the *Grabbed Image* [see Batlle et al. Fig. 2] plane, or the shape corresponding to obtained 3D information) from the captured image(s) (Batlle et al. page 965, left column, lines 6-10).

(15.d.) Generating three dimensional shape data of the three dimensional object based on the shape. See Batlle et al. page 965, left column, lines 6-10 and Batlle et al. sections 4.1 and 4.3.

37. For the reasons given above, one can consider the silhouette-based representation (obtained by above step (15.c) of Niem) of an object a *rough shape* estimation of the object, relative to the representation obtained via the SL method (step (15.d of Batlle et al.)). Conversely, one can consider the representation obtained via the SL method a *detailed shape* estimation of the object, relative to a silhouette-based representation. Therefore, Niem suggests (Niem, page 1, right column, item (i)) calculating both a rough shape (i.e. silhouette-based model) and detailed shape (e.g. SL model such as those described by Batlle et al.), and using those shapes to generate three dimensional shape data of a three dimensional object.

38. Though neither Niem nor Batlle et al. explicitly suggest that the rough shape and detailed shape be obtained by the same image(s) (i.e. the image(s) of the object illuminated by the projected pattern), this aspect would be inherent to Niem's suggested combination of the SFS and SL methods. Since the SL method consists of projecting a pattern onto a three dimensional object, Niem's suggested combination of the SFS and SL methods entails the capture of an image(s) of the object illuminated by the projected pattern. As further suggested by Niem, the silhouette can be obtained by chroma-keying or color-keying (e.g. blue-screening – Niem page 1, left column, last paragraph), which can acquire the silhouette of the object even with a light pattern projected thereon[2]. Therefore, it is reasonable to assume that, in a method that combines the SFS and SL methodologies, the image(s), from which the rough shape (i.e. the silhouette-based representation) and the detailed shape (e.g. an SL model) are derived, is the same (i.e. the image(s) in steps $(15.a_1)$ and $(15.a_2)$ can be considered the same).

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2 Capturing separate images under different lighting conditions is impractical and even undesirable since it introduces unnecessary processing and complexity to the method and, moreover, may introduce inconsistency between the captured images.

39. The teachings of Niem and Batlle et al. are combinable because they are analogous art. Specifically, the teachings of Niem and Batlle et al. are both directed toward the construction of a 3D model of an object from multiple views. Moreover, Niem provides an explicit suggestion of combinability (see above). Therefore, it would have been obvious to one of ordinary skill in the art, at the time of the applicant's claimed invention, to combine an SFS reconstruction method, in the manner suggested by Niem, with an SL method to obtain an accurate 3D representation of an object. The motivation to do so would have been to accurately represent surface concavities of the object that may otherwise have been missed by using an SFS technique alone. Extending an SFS method by combining it with a SL, in the manner discussed above, yields a three dimensional modeling method that conforms to that which is set forth in claim 15.

40. *The following is in regard to Claim 3 and 27.* Claims 3 and 27 recite substantially the same limitations as claim 15. (These claims respectively propose an apparatus and stored computer program implementing the method of claim 15). Therefore, with regard to claims 3 and 27, remarks analogous to those presented above with regard to claim 15 are applicable.

41. *The following is in regard to Claims 4, 16, and 28.* Note that these claims deviate from claims 3, 15, and 27, respectively, only in that the aforementioned rough shape is input or captured, as opposed to being calculated. This does not introduce anything significant over claims 3, 15 and 27, respectively, since the calculated rough shape data may just as well be regarded as input data. In this way, claims 4 , 16 and 28 can be regarded as reciting substantially the same limitations as claim 3, 15, and 27, respectively. Therefore, with regard to claims 4, 16 and 28, remarks analogous to those presented above with regard to claim 3, 15, and 27 are respectively applicable.

42. *The following is in regard to Claim 44.* As shown above, the teachings of Niem and Batlle et al., when combined in manner discussed above, adequately satisfy the limitations of claim 3. Generally, 3D reconstruction from captured images involves:

(44.a.) Image input is performed such that the images are captured at least two different points at different locations. For example, the SFS method necessitates this. See Niem page 1, Fig. 1(b) and left column, last paragraph.

Furthermore, coded structured light (CSL) reconstruction involves:

(44.b.) Detailed shape (see above) calculation entails extracting a portion in said input image where color or density changes. Refer to, for instance, Batlle et al. Fig. 3 (page 969) and the corresponding description in Batlle et al. Section 6.1. The various patterns are projected onto the scene. Notice these patterns consist of color or density changes and are detected by the camera, during the 3D scene reconstruction. Also, notice that temporal changes in the color or density of the projected patterns are also observed during reconstruction (paragraph 2 of Batlle et al. Section 6.1).

(44.c.) The detailed shape is derived by matching of potions where color or density changes is performed between input images, to calculate the three dimensional shape of said three dimensional object. This can be understood from Batlle et al. page 963, lines 4-9 and lines 6-8 of the Abstract. Color or density changes are encoded for each imaged region and, from the obtained codes, a correspondence (matching) is derived between corresponding regions of the captured image and the projected image (Batlle et al. page 965, Fig. 2).

A CSL methodology has the advantage that it greatly simplifies the correspondence problem (Batlle et al. page 963, right column, lines 4-5). It would, therefore, have been obvious to one of ordinary skill in the art, at the time of the applicant's claimed invention, to use a CSL methodology (e.g. Posdamer et al.'s CSL method – Batlle et al. Section 6.1), as an SL method in Niem's suggested combination of the SFS and SL methodologies. In this way, an apparatus implementing the method obtained by combining the SFS and CSL methods, as proposed by Niem and discussed above, would conform to the three dimensional modeling apparatus set forth in claim 15.

43. *The following is in regard to Claim 54.* Niem discloses a robust approach for the automatic 3D reconstruction of an object, from multiple camera views, using a *shape-from-silhouette* (SFS) technique (Niem page 1, left column, last paragraph). Niem further suggests extending this technique by incorporating a *Structured Light* (SL) methodology to accommodate the concave surfaces of the observed object (Niem, page 1, right column, item (i)). This extended method involves:

(54.b.) Inputting (i.e. capturing) an image(s) of the three dimensional object (e.g. input images – Niem page 1, left column, last paragraph). See, for example, Niem Fig. 1(b).

(54.c_1) Calculating a shape (e.g. a silhouette or the or the bounding volume corresponding to obtained 3D information) from the captured image(s). See Niem page 1, right column, last paragraph.

44. While the step of (54.a) projecting pattern light onto a three dimensional object is critical to SL methods, and, therefore, inherent to Niem's suggested extension of the aforementioned SFS method, Niem does not expressly demonstrate this step. SL methods also include the step of (54.c_2) calculating a shape from captured images, by at least extracting a pattern projected region and pattern border region the said input image(s) to calculate the three dimensional shape of said three dimensional object based on these regions. Again, while this step would be inherent to the extended SFS of Niem, it is not explicitly shown by Niem.

45. Batlle et al. disclose numerous *Structured-Light* methods to obtain 3D information to be used in the construction of 3D surfaces (presumably of objects – Batlle et al. Abstract). Generally speaking, Structured-Light methods involve:

(54.a.) Projecting pattern light onto a three dimensional object (i.e. "projecting a given pattern on the measuring surfaces" – Batlle et al. Abstract, lines 5-6).

(54.b.) Inputting (i.e. capturing) an image(s) of the three dimensional object (Batlle et al. page 965, left column, lines 5-6).

(54.c_2) Calculating a shape (i.e. either the 2D deformed pattern projected on the *Grabbed Image* [see Batlle et al. Fig. 2] plane, or the shape corresponding to obtained 3D information) from the captured image(s) (Batlle et al. page 965, left column, lines 6-10), wherein calculating a shape from captured images involves at least extracting a pattern projected region (e.g. the patterns depicted in Batlle et al. Fig. 3) and pattern border region (e.g. the borders between the light and dark regions of the patterns depicted in Batlle et al. Fig. 3) the said input image(s) to calculate the three dimensional shape of said three dimensional object based on these regions. See Batlle et al. page 965, left column, lines 6-10 and

Batlle et al. sections 4.1 and 4.3.

46. The teachings of Niem and Batlle et al. are combinable because they are analogous art. Specifically, the teachings of Niem and Batlle et al. are both directed toward the construction of a 3D model of an object from multiple views. Moreover, Niem provides an explicit suggestion of combinability (see above). Therefore, it would have been obvious to one of ordinary skill in the art, at the time of the applicant's claimed invention, to combine an SFS reconstruction method, in the manner suggested by Niem, with an SL method to obtain an accurate 3D representation of an object. The motivation to do so would have been to accurately represent surface concavities of the object that may otherwise have been missed by using an SFS technique alone. Extending an SFS method by combining it with a SL, in the manner discussed above, yields a three dimensional modeling method that conforms to that which is set forth in claim 54.

47. *The following is in regard to Claim 56*. As shown above, the teachings of Niem and Batlle et al., when combined in manner discussed above, adequately satisfy the limitations of claim 54. Furthermore, Batlle et al. suggest the usage of a plurality of binary patterns as the projected pattern light. See Batlle et al. Fig. 3 and the second paragraph (first sentence) of Batlle et al. Section 6.1. In this way, the method obtained by combining the SFS and CSL methods, as proposed by Niem and discussed above, would conform to the three dimensional modeling method set forth in claim 56.

48. *The following is in regard to Claim 57.* As shown above, the teachings of Niem and Batlle et al., when combined in manner discussed above, adequately satisfy the limitations of claim 54. Furthermore, Batlle et al. suggest the capture of image from at least two different locations. See, for example, the Introduction of Batlle et al., left column, lines 5-8. Moreover, it should be clear that repeating the SL reconstruction for multiple viewpoints about the object is necessary to obtain a full 3D representation of the object. In this way, the method obtained by combining the SFS and CSL methods, as proposed by Niem and discussed above, would conform to the three dimensional modeling method set forth in claim 57.

49. *The following is in regard to Claims 38, 40 and 41.* Claims 38 and 40-41 recite substantially the same limitations as claims 54 and 56-57, respectively. (These claims propose an apparatus implementing the method of claim 54 and 56-57, respectively). Therefore, with regard to claims 38 and 40-41 remarks analogous to those presented above with regard to claims 54 and 56-57 are respectively applicable.

50. *The following is in regard to Claims 39.* As shown above, the teachings of Niem and Batlle et al., when combined in manner discussed above, adequately satisfy the limitations of claim 1. Note that, when taking into account the subject matter inherited from parent claim 1, claim 39 puts forth substantially the same limitations as claim 38. Therefore, with regard to claim 39 remarks analogous to those presented above with regard to claim 38 are applicable.

51. *The following is in regard to Claims 55.* As shown above, the teachings of Niem and Batlle et al., when combined in manner discussed above, adequately satisfy the limitations of claim 1. Note that, when taking into account the subject matter inherited from parent claim 13, claim 55 puts forth substantially the same limitations as claim 54. Therefore, with regard to claim 55 remarks analogous to those presented above with regard to claim 54 are applicable.

52. *The following is in regard to Claim 58.* Niem discloses a robust approach for the automatic 3D reconstruction of an object, from multiple camera views, using a *shape-from-silhouette* (SFS) technique (Niem page 1, left column, last paragraph). Niem further suggests extending this technique by incorporating a *Structured Light* (SL) methodology to accommodate the concave surfaces of the observed object (Niem, page 1, right column, item (i)). This extended method involves:

(58.b.) Inputting (i.e. capturing) an image(s) of the three dimensional object (e.g. input images – Niem page 1, left column, last paragraph). See, for example, Niem Fig. 1(b).

(58.c_1) Calculating a shape (e.g. a silhouette or the or the bounding volume corresponding to obtained 3D information) from the captured image(s). See Niem page 1, right column, last paragraph.

53. While the step of (58.a) projecting pattern light onto a three dimensional object is critical to SL methods, and, therefore, inherent to Niem's suggested extension of the aforementioned SFS method, Niem does not expressly demonstrate this step. SL methods also include the step of (58.c_2) calculating a shape from captured images, by:

(58.c_2.1) Extracting a portion in said input image where color or density changes.

(58.c_2.2) Matching portions where color or density changes between input images.

Again, while this step would be inherent to the extended SFS of Niem, it is not explicitly shown by Niem.

54. Batlle et al. disclose numerous *Structured-Light* methods to obtain 3D information to be used in the construction of 3D surfaces (presumably of objects – Batlle et al. Abstract). Generally speaking, Structured-Light methods involve:

(54.a.) Projecting pattern light onto a three dimensional object (i.e. "projecting a given pattern on the measuring surfaces" – Batlle et al. Abstract, lines 5-6).

(54.b.) Inputting (i.e. capturing) an image(s) of the three dimensional object (Batlle et al. page 965, left column, lines 5-6).

(54.c_2) Calculating a shape (i.e. either the 2D deformed pattern projected on the *Grabbed Image* [see Batlle et al. Fig. 2] plane, or the shape corresponding to obtained 3D information) from the captured image(s) (Batlle et al. page 965, left column, lines 6-10).

Step (54.c_2) includes:

(58.c_2.1) Extracting a portion in said input image where color or density changes. See, for example, Batlle et al. Section 3, paragraph 1 and Figs. 3-4.

(58.c_2.2) Matching portions where color or density changes (e.g. spatio-temporal color/density changes encapsulated by the codification of the projected patterns) between input images. See, for example, Batlle et al. Section 3, Fig. 2, paragraphs 2-5 of Section 5, and page 972, right column, paragraph 1.

Furthermore, Batlle et al. suggest the capture of image (step (58.b) above) from at least two different locations. See, for example, the Introduction of Batlle et al., left column, lines 5-8. Moreover, it should be clear that repeating the SL reconstruction for multiple viewpoints about the object is necessary to obtain a full 3D representation of the object.

55. The teachings of Niem and Batlle et al. are combinable because they are analogous art. Specifically, the teachings of Niem and Batlle et al. are both directed toward the construction of a 3D model of an object from multiple views. Moreover, Niem provides an explicit suggestion of combinability (see above). Therefore, it would have been obvious to one of ordinary skill in the art, at the time of the applicant's claimed invention, to combine an SFS reconstruction method, in the manner suggested by Niem, with an SL method to obtain an accurate 3D representation of an object. The motivation to do so would have been to accurately represent surface concavities of the object that may otherwise have been missed by

using an SFS technique alone. Extending an SFS method by combining it with a SL, in the manner discussed above, yields a three dimensional modeling method that conforms to that which is set forth in claim 58.

56. *The following is in regard to Claim 60.* As shown above, the teachings of Niem and Batlle et al., when combined in manner discussed above, adequately satisfy the limitations of claim 58. Batlle et al. suggest that color structured patterns can be projected onto a object or scene. Batlle et al. further suggest that hue be used for the color pattern generation, thus implying the usage of a color model using hue (e.g. HSI, HSV, etc). See Batlle et al. Section 5, **Colour**. Furthermore, Batlle et al. suggest that the correlation between adjacent pattern elements be small so that strong contrast exists between at element borders (i.e. "the hue values have to be quite different from each other"). Adjacent stripes having a hue-shift of 90° would easily satisfy this limitation. See Batlle et al. Section 5, **Colour** and paragraph 1 of section 6.8 (page 976).

57. Given the teachings of Batlle et al. It would have been obvious to one of ordinary skill in the art, at the time of the applicant's claimed invention, to utilize a color SL pattern, consisting of relatively uncorrelated hues, as the pattern projected onto the object undergoing 3D reconstruction. One clear advantage of using a color patterns, in CSL schemes such as those presented by Batlle et al., is that the code basis is extended beyond two symbols (e.g. colors), as in binary. This allows more information (more codes) to be presented per captured image. Using a color SL pattern in the method obtained by combining the SFS and CSL methods, as proposed by Niem and discussed above, yields a modeling method that conform to the three dimensional modeling method set forth in claim 60.

58. *The following is in regard to Claim 61.* As shown above, the teachings of Niem and Batlle et al., when combined in manner discussed above, adequately satisfy the limitations of claim 58. Generally, in coded SL methods, matching of the portions where color or density changes (e.g. spatio-temporal color/density changes encapsulated by the codification of the projected patterns) is obtained based on properties of the portions where color or density changes, which are obtained from the input image(s). See Batlle et al. Fig. 2. In this way, the method obtained by combining the SFS and CSL methods, as proposed by Niem and discussed above, would conform to the three dimensional modeling method set forth in claim 61.

59. *The following is in regard to Claim 62.* As shown above, the teachings of Niem and Batlle et al., when combined in manner discussed above, adequately satisfy the limitations of claim 61. Generally, in coded SL methods, the property of the portion where color or density changes is color information regarding portions located to the left and right of, or above and below, said portion where color or density changes in said input images. See Batlle et al. Fig. 2. In this way, the method obtained by combining the SFS and CSL methods, as proposed by Niem and discussed above, would conform to the three dimensional modeling method set forth in claim 62.

60. *The following is in regard to 42 and 45-47.* Claims 42 and 45-47 recite substantially the same limitations as claims 58 and 60-62, respectively. (These claims propose an apparatus implementing the method of claims 58 and 60-62, respectively). Therefore, with regard to claims 42 and 45-47 remarks analogous to those presented above with regard to claims 58 and 60-62 are respectively applicable.

61. *The following is in regard to Claim 43.* As shown above, the teachings of Niem and Batlle et al., when combined in manner discussed above, adequately satisfy the limitations of claim 1. Note that when taking into account the subject matter inherited from parent claim 1, claim 43 puts forth substantially the same limitations as claim 42. Therefore, with regard to claim 43 remarks analogous to those presented above with regard to claim 42 are applicable.

62. *The following is in regard to Claim 59.* As shown above, the teachings of Niem and Batlle et al., when combined in manner discussed above, adequately satisfy the limitations of claim 13. Note that when taking into account the subject matter inherited from parent claim 13, claim 59 puts forth substantially the same limitations as claim 58. Therefore, with regard to claim 59 remarks analogous to those presented above with regard to claim 58 are applicable.

63. Claims 5-6, 8-9, 17-18, 20-21, 29-30, and 32-33 are rejected under 35 U.S.C. 103(a) as being unpatentable over Niem, in view of Batlle, et al., in further view of Wojciech et al. ("Image-Based Visual Hulls", SIGGRAPH 2000).

64. *The following is in regard to Claim 17.* As shown above, the teachings of Niem and Batlle et al., when combined in manner discussed above, adequately satisfy the limitations of claim 13. Though it can be

argued that, in the extended SFS/SL method of Niem and Batlle et al, the step of generating three dimensional shape data inherently includes the following aspects:

(17.a.) Determining the final three dimensional shape data based on the following rule:

(17.b.) If the detailed shape exists inside the rough shape, then the detailed shape is the final three dimensional shape data of said object

(17.c.) Else the rough shape is taken as the final three dimensional shape data of said object

these aspects are not expressly disclosed by either Niem or Batlle et al.

65. Wojciech et al. disclose an SFS method employing the concept of *visual hulls.* A visual hull is volumetric representation formed essentially of the intersections of silhouette cones. It will always contain the object. Refer to *Visual Hull* in Section 2 and Fig. 1 of Wojciech et al. Again concave surfaces cannot be accounted for (last sentence of paragraph 2 of *Visual Hull* in Section 2 of Wojciech et al.). In this manner, the visual hull represents a rough shape, as discussed before. Wojciech et al. refine this model by "carving" away (*calculatus eliminatus* – Wojciech et al. page 1, right column paragraph 1) regions inside the visual hull where the object is not. In other words, Wojciech et al. obtains a model of an object such that:

(17.b.) If the detailed shape (i.e. the carved-away model) exists inside the rough shape, then the detailed shape is the final three dimensional shape data of said object.

(17.c.) Else the rough shape (i.e. the visual hull) is taken as the final three dimensional shape data of said object.

This observation follows from the carving away process discussed above.

66. Wojciech et al. is combinable with the Niem and Batlle et al. because they are analogous art. Specifically, Wojciech et al. teaches an SFS method and Niem teaches using an SFS method in conjunction with an SL method (e.g. those taught by Batlle et al.). Therefore, it would have been obvious to one of ordinary skill in the art, at the time of the applicant's claimed invention, to use the visual hull method of Wojciech et al. for SFS reconstruction in the method obtained by combining the SFS and SL methods in accordance with the teachings of Niem and Batlle et al. Furthermore, having the SL framework at his/her disposal, it would have been obvious to one of ordinary skill in the art, at the time of the applicant's claimed invention, to use an SL reconstructed model as the detailed shape in step (17.b) above. The motivation to

use the visual hull method of Wojciech et al. as the SFS method would have been that it overcomes computational expense of CSG/volumetric shape-from-silhouette methods discussed by Niem (Niem page 1, left column, paragraph 1, sentence 1). See Wojciech et al. page 1, right column, paragraph 2. The motivation to use the SL derived model as the detailed shape would have been that it would replace the expensive carving operation suggested by Wojciech et al. with a simple decision as to whether a voxel lies within the visual hull (e.g. steps (17.b)-(17.c) above). Combining the teachings of Wojciech et al., Batlle et al. and Niem, in the manner just described, would yield a modeling method that conforms to that which is set forth in claim 17.

67. *The following is in regard to Claim 18.* As shown above, the teachings of Niem and Batlle et al., when combined in manner discussed above, adequately satisfy the limitations of claim 13. Though it can be argued that, in the extended SFS/SL method of Niem and Batlle et al, the step of generating three dimensional shape data inherently includes obtaining a region where the object surface can exist based on the rough shape, to generate three dimensional shape data of said three dimensional object based on the rough shape, the detailed shape, and the region where the object surface can exist, this is not explicitly shown by either Niem or Batlle et al.

68. Wojciech et al. disclose an SFS method employing the concept of *visual hulls.* A visual hull is volumetric representation formed essentially of the intersections of silhouette cones. It will always contain the object. Refer to *Visual Hull* in Section 2 and Fig. 1 of Wojciech et al. Again concave surfaces cannot be accounted for (last sentence of paragraph 2 of *Visual Hull* in Section 2 of Wojciech et al.). In this manner, the visual hull represents a rough shape, as discussed before. Wojciech et al. refine this model by "carving" away (*calculatus eliminatus* – Wojciech et al. page 1, right column paragraph 1) regions inside the visual hull where the object is not. In other words, the surface and inside of the visual hull represents a "region where the object surface can exist based on the rough shape". Therefore, 3D reconstruction, according to Wojciech et al.'s visual hull method, is based on a rough shape (i.e. the visual hull) and a region where the object surface can exist (all points within and on the visual hull).

69. Wojciech et al. is combinable with the Niem and Batlle et al. because they are analogous art. Specifically, Wojciech et al. teaches an SFS method and Niem teaches using an SFS method in conjunction with an SL method (e.g. those taught by Batlle et al.). Therefore, it would have been obvious to one of

ordinary skill in the art, at the time of the applicant's claimed invention, to use the visual hull method of Wojciech et al. for SFS reconstruction in the method obtained by combining the SFS and SL methods in accordance with the teachings of Niem and Batlle et al. The motivation to use the visual hull method of Wojciech et al. as the SFS method would have been that it overcomes computational expense of CSG/volumetric shape-from-silhouette methods discussed by Niem (Niem page 1, left column, paragraph 1, sentence 1). See Wojciech et al. page 1, right column, paragraph 2. Recall that, in the method obtained by extending an SFS method by combining it with a SL, in the manner discussed above and by Niem, three dimensional shape data of the object is generated based on a rough shape (SFS reconstruction) and detailed shape (SL reconstruction. Therefore, by combining the method of Niem and Batlle et al. with that of Wojciech et al., in the manner just described, one obtains a method, in accordance with claim 13, wherein generating three dimensional shape data includes obtaining a region where the object surface can exist based on the rough shape, to generate three dimensional shape data of said three dimensional object based on the rough shape, the detailed shape, and the region where the object surface can exist.

70. *The following is in regard to Claim 20.* As shown above, the teachings of Niem and Batlle et al., when combined in manner discussed above, adequately satisfy the limitations of claim 13. Though it can be argued that, in the extended SFS/SL method of Niem and Batlle et al, the step of calculating a detailed shape includes setting a region where the object surface cannot exist in a portion inside the rough shape and determining a region inside the rough shape other than said region where the object surface cannot exist as a region where the object surface can exist, to generate three dimensional shape data of said three dimensional object based on the rough shape, the detailed shape, and the region where the object surface can exist, neither Niem nor Batlle et al. explicitly show such a step.

71. Wojciech et al. disclose an SFS method employing the concept of *visual hulls.* A visual hull is volumetric representation formed essentially of the intersections of silhouette cones. It will always contain the object. Refer to *Visual Hull* in Section 2 and Fig. 1 of Wojciech et al. Again concave surfaces cannot be accounted for (last sentence of paragraph 2 of *Visual Hull* in Section 2 of Wojciech et al.). In this manner, the visual hull represents a rough shape, as discussed before.

72. Wojciech et al. refine this model by "carving" away (*calculatus eliminatus* – Wojciech et al. page 1, right column paragraph 1) regions inside the visual hull where the object is not. Observing a captured

image(s), Wojciech et al. determines whether pixels in the image(s) correspond to visible regions of the object or regions that are occluded by the visual hull. See Wojciech et al. Fig. 4 and page 4, left column, last paragraph and right column, first paragraph. Also refer to Wojciech et al. page 5, paragraphs 1-3. Self-occluding regions (e.g. regions occluded by the actual (unknown) geometry of the object or the visual hull) are marked as not visible. Points that are not occluded are marked as visible. See, for example, Wojciech et al. page 4, Fig. 4, right column paragraph 1, and the pseudocode in the right column. Wojciech et al.'s visual hull method, therefore, includes setting a region where the object surface cannot exist (i.e. "not visible" marked regions) and a portion inside the rough shape (i.e. the visual hull) and determining a region inside the rough shape other than said region where the object surface cannot exist as a region where the object surface can exist (i.e. "visible" marked regions).

73. Wojciech et al. is combinable with the Niem and Batlle et al. because they are analogous art. Specifically, Wojciech et al. teaches an SFS method and Niem teaches using an SFS method in conjunction with an SL method (e.g. those taught by Batlle et al.). Therefore, it would have been obvious to one of ordinary skill in the art, at the time of the applicant's claimed invention, to use the visual hull method of Wojciech et al. for SFS reconstruction in the method obtained by combining the SFS and SL methods in accordance with the teachings of Niem and Batlle et al. The motivation to use the visual hull method of Wojciech et al. as the SFS method would have been that it overcomes computational expense of CSG/volumetric shape-from-silhouette methods discussed by Niem (Niem page 1, left column, paragraph 1, sentence 1). See Wojciech et al. page 1, right column, paragraph 2. It would have also been obvious to one of ordinary skill in the art, at the time of the applicant's claimed invention, to use points that are marked visible (i.e. existent regions) to generate three dimensional shape data of the three dimensional object. Clearly the motivation for this would have been to constrain the model only those points that are visible in some view (as opposed to including points that are not visible in all views), thereby, eliminating extraneous points from the model and/or model computation. Combining the teachings of Wojciech et al., Niem and Batlle et al., in the manner just described, would yield a modeling method that conforms to the 3D modeling method set forth in claim 20.

74. *The following is in regard to Claim 21.* As shown above, the teachings of Niem and Batlle et al., when combined in manner discussed above, adequately satisfy the limitations of claim 13. Though it can be

argued that, in the extended SFS/SL method of Niem and Batlle et al., the step of generating three dimensional shape data includes determining a final object surface location candidate from a plurality of object surface location candidates based on a region where the object surface can exist and generating three dimensional shape data of said three dimensional object based on said final object surface location candidate, this step is not explicitly shown by either of Niem or Batlle et al.

75. Wojciech et al. disclose an SFS method employing the concept of *visual hulls.* A visual hull is volumetric representation formed essentially of the intersections of silhouette cones. It will always contain the object. Refer to *Visual Hull* in Section 2 and Fig. 1 of Wojciech et al. Again concave surfaces cannot be accounted for (last sentence of paragraph 2 of *Visual Hull* in Section 2 of Wojciech et al.). In this manner, the visual hull represents a rough shape, as discussed before. Wojciech et al. refine this model by "carving" away (*calculatus eliminatus* – Wojciech et al. page 1, right column paragraph 1) regions inside the visual hull where the object is not. In other words, the surface and inside of the visual hull represents a "region where the object surface can exist". Points inside the visual hull would therefore constitute surface location candidates. (Points that are marked visible [Wojciech et al. page 4, right column paragraph 1] could also be considered location candidates).

76. Wojciech et al. is combinable with the Niem and Batlle et al. because they are analogous art. Specifically, Wojciech et al. teaches an SFS method and Niem teaches using an SFS method in conjunction with an SL method (e.g. those taught by Batlle et al.). Therefore, it would have been obvious to one of ordinary skill in the art, at the time of the applicant's claimed invention, to use the visual hull method of Wojciech et al. for SFS reconstruction in the method obtained by combining the SFS and SL methods in accordance with the teachings of Niem and Batlle et al. The motivation to use the visual hull method of Wojciech et al. as the SFS method would have been that it overcomes computational expense of CSG/volumetric shape-from-silhouette methods discussed by Niem (Niem page 1, left column, paragraph 1, sentence 1). See Wojciech et al. page 1, right column, paragraph 2. Given the discussion above, it should be clear that combining the teachings of Wojciech et al. with those of Niem and Batlle et al., yields a method, in accordance with claim 13, wherein the step of generating three dimensional shape data includes determining a final object surface location candidates (i.e. points composing the SL reconstruction of the object) from a plurality of object surface location candidates (i.e. points on and within the visual hull) based

on a region (i.e. the visual hull) where the object surface can exist and generating three dimensional shape data of said three dimensional object based on the final object surface location candidates. Such a method is in accordance with claim 21.

77. *The following is in regard to Claims 5-6 and 8-9.* Claims 5-6 and 8-9 recite substantially the same limitations as claims 17-18 and 20-21, respectively. (These claims respectively propose an apparatus implementing, respectively, the methods of claims 17-18 and 20-21). Therefore, with regard to claims 5-6 and 8-9, remarks analogous to those presented above with regard to claim 17-18 and 20-21 are respectively applicable.

78. *The following is in regard to Claims 29-30 and 32-33.* Claims 29-30 and 32-33 recite substantially the same limitations as claims 17-18 and 20-21, respectively. (These claims respectively propose a stored computer program implementing, respectively, the methods of claims 17-18 and 20-21). Therefore, with regard to claims 29-30 and 32-33, remarks analogous to those presented above with regard to claim 17-18 and 20-21 are respectively applicable.

79. Claims 63-64 are rejected under 35 U.S.C. 103(a) as being unpatentable over Niem, in view of Batlle, et al., in further view of Gonzalez et al. ("Digital Image Processing", 1rst Edition).

80. *The following is in regard to Claim 63.* As shown above, the teachings of Niem and Batlle et al., when combined in manner discussed above, adequately satisfy the limitations of claim 61. Neither Niem nor Batlle et al. show averaging being performed on the input images when said property is obtained.

81. Image averaging is known to reduce noise in images. See Section 4.2.4 of Gonzalez et al.

82. The teachings of Gonzalez et al. are combinable with those of Niem and Batlle et al. because they are analogous art. Specifically, each concern processing of digital images captured of an object. Therefore, it would have been obvious to one of ordinary skill in the art, at the time of the applicant's claimed invention, to average the input images when said property is obtained. The motivation to do so would have been to reduce noise, thereby improving the accuracy with which the correspondence between images can be derived. Incorporating image averaging into the method obtained by combining the SFS and CSL

methods, as proposed by Niem and discussed above, would yield a modeling method that conforms to the three dimensional modeling method set forth in claim 63.

83. *The following is in regard to Claim 64.* As shown above, the teachings of Niem and Batlle et al., when combined in manner discussed above, adequately satisfy the limitations of claim 63. Clearly, averaging an input image is equivalent to averaging each of the divided regions of the image, and vice versa. It should also be clear from Section 4.2.4 of Gonzalez et al. that arbitrary sections of an image may be averaged. Taking this into account, the discussion above with regard to claim 63 sufficiently addresses the subject matter of claim 63. Therefore, incorporating image averaging into the method obtained by combining the SFS and CSL methods, as proposed by Niem and discussed above, would yield a modeling method that conforms to the three dimensional modeling method set forth in claim 64.

84. *The following is in regard to 48-49.* Claims 48-49 recite substantially the same limitations as claims 63-64, respectively. (These claims propose an apparatus implementing the method of claims 58 and 60-62, respectively). Therefore, with regard to claims 48-49 remarks analogous to those presented above with regard to claims 63-64 are respectively applicable.

85. Claims 53 and 67 are rejected under 35 U.S.C. 103(a) as being unpatentable over Niem, in view of Crampton (U.S. Patent 6,611,617).

86. *The following is in regard to Claim 67.* As shown above, Niem discloses an apparatus that conforms to that which is set forth in claim 66. Niem, however, does not expressly show or suggest controlling the position of the second three dimensional shape measuring means, said control means being controlled based on said rough shape information obtained by said first three dimensional measuring means.

87. Crampton discloses an SL scanning apparatus for obtaining 3D models of scanned objects. The scanning apparatus has a means (e.g. control unit 2, Crampton Fig. 1) to control the position of the aforementioned second three dimensional measuring means (e.g. an SL scanning means – Crampton column 6, lines 8-22). The arm (e.g. arm 1 – Crampton Fig. 1 and column 2, lines 34-47), and consequently the 3D measuring means, of Crampton's apparatus moves according to a "library" of predefined range

images (Crampton column 17, lines 54-67 to column 18, lines 1-6). According to Crampton (Crampton column 17, lines 54-67 to column 18, lines 1-6 and column 26, lines 51-55), this library may include rough default range images (e.g. cylinders or cubes). Thus, Crampton demonstrates controlling the position of the second three dimensional shape measuring means, said control means being controlled based on said rough shape information.

88. The teachings of Crampton are combinable with those of Niem because they are analogous art. Specifically, both Crampton and Niem disclose methods and systems for 3D reconstruction using SL methodologies. Therefore, it would have been obvious to one of ordinary skill in the art, at the time of the applicant's claimed invention, to control the position of the 3D measuring means (e.g. the camera of Niem or the aforementioned 3D scanning means of Crampton) in accordance with a rough depth image, as taught by Crampton. Recall that, in the method of Niem, a rough 3D reconstruction (SFS reconstruction) is derived prior to deriving a detailed 3D reconstruction (SL reconstruction) of the object. Given this, it would have also been obvious to one of ordinary skill in the art, at the time of the applicant's claimed invention, to control the position of the 3D measuring means (e.g. the camera of Niem or the aforementioned 3D scanning means of Crampton) in accordance with the previously derived 3D SFS reconstruction (e.g. by simply adding it to Crampton's library of range images). The motivation for doing so would have been to provide an automated means to capture images and reconstruct a 3D model from multiple viewpoints about the object. The motivation to use the SFS reconstruction as the rough shape guiding the position control would have been to refine the SFS reconstruction by accounting for concavities. Combining the teachings of Crampton and Niem, in this manner, would yield a modeling apparatus that conforms to the 3D modeling apparatus set forth in claim 67.

89. *The following is in regard to Claim 53.* Claim 53 recites substantially the same limitations as claim 67. (*Moving* is essentially the same as *controlling the position* and the three dimensional shape input means having higher three dimensional input accuracy and the three dimensional shape input means having lower three dimensional input accuracy are essentially the same as the aforementioned detailed and rough shapes, respectively). Therefore, with regard to claims 53 remarks analogous to those presented above with regard to claims 67 are applicable.

90. Claims 50-51 are rejected under 35 U.S.C. 103(a) as being unpatentable over Niem, in view of Batlle et al., in further view of Crampton.

91. *The following is in regard to Claim 50.* As shown above, the teachings of Niem and Batlle et al., when combined in manner discussed above, adequately satisfy the limitations of claim 1. Neither Niem nor Batlle et al. expressly show or suggest a 3D modeling apparatus that further includes a moving means for moving said projection means and said image input means.

92. Crampton discloses an SL scanning apparatus for obtaining 3D models of scanned objects. The scanning apparatus has a means (e.g. control unit 2, Crampton Fig. 1) for moving projection means (e.g. an SL scanning means – Crampton column 6, lines 8-22). See Crampton column 2, lines 34-47.

93. The teachings of Crampton are combinable with those of Niem because they are analogous art. Specifically, Crampton, Batlle et al. and Niem all disclose methods and systems for 3D reconstruction using SL methodologies. Therefore, it would have been obvious to one of ordinary skill in the art, at the time of the applicant's claimed invention, to change the position of the SL projection means in the apparatus, implementing the extended SFS method discussed above, using an arm-like apparatus such as that which is depicted in Fig. 1 of Crampton. The motivation to do so would have been to provide an automated means to capture images and reconstruct a 3D model from multiple viewpoints about the object. Combining the teachings of Niem, Batlle et al., and Crampton, in this manner, yields an 3D modeling apparatus that conforms to that which is set forth in claim 50.

94. *The following is in regard to Claim 51.* As shown above, the teachings of Niem, Batlle et al. and Crampton, when combined in manner discussed above, adequately satisfy the limitations of claim 50. In a manner analogous to that which was presented above with regard to claim 67, the modeling apparatus obtained by combining the teachings of Niem, Batlle et al., and Crampton can be straightforwardly modified by one of ordinary skill in the art so that the moving means moves the projection means (analogous to the second 3D shape measuring means discussed above relative to claim 67) and image input via this projection means (i.e. its movement) is based on said rough shape. See the discussion above relating to claim 67. Therefore, combining the teachings of Niem, Batlle et al., and Crampton, in this manner, yields an 3D modeling apparatus that conforms to that which is set forth in claim 51.

Citation of Relevant Prior Art

95. The prior art made of record and not relied upon is considered pertinent to applicant's disclosure:

[1] *The Visual Concept for Silhouette-Based Image Understanding*. Laurentini. IEEE, PAMI, 1994.

Laurentini introduces the concept of visual hulls as a shape-from-silhouette method for generating three dimensional models of objects from 2Dimages. The paper provides more theoretical background relating to the concept of visual hulls than does Wojciech et al.

[2] *Construction of 3D Models of Objects Using Combination of Shape From Silhouette and Shape from Structure Light.* Tosovic. July 2001.

Tosovic propose building a rough reconstruction of an object using shape-from-silhouette methods and refining this initial model by using structured light techniques.

[3] *On Combining Shape from Silhouette and Shape from Structured Light.* Tosovic, et al. 2002.

Tosovic et al. propose building a rough reconstruction of an object using shape-from-silhouette methods and refining this initial model by using structured light techniques.

[4] *Solid Model Acquisition from Range Imagery.* Reed. 1998.

Reed suggests (section 2.3.1) extending a visual-hull based reconstruction method by utilizing range data or range imagery. Structured light techniques are typically classified as active ranging techniques.

[5] *Stripe Boundary Codes for Real-Time Structured-Light Range Scanning of Moving Objects.* Hall-Holt, et al. IEEE ICCV 2001.

Hall-Holt et al. use structured light range scanning to capture 3D models of moving objects. Hall-Holt et al. project striped binary patterns that vary temporally onto the scanned objects. Of particular relevance to the Applicant's invention is Hall-Holt et al.'s discussion of stripe boundary codes. Hall-Holt et al. assign codes to stripes of the illumination pattern and

observes code transitions at the stripe boundaries (i.e. pattern border regions). As in the Applicant's claimed invention these are used to resolve ambiguities that may arise in deriving the correspondences between images (in this case the projected image and captured image). The graph shown in Hall-Holt provides a decision framework for resolving such ambiguities. It is similar to the correspondences shown on page 45 of the Applicant's disclosure.

[6] *Range Data Acquisition Using Color Structured Lighting and Stereo Vision.* Chen, et al. 1997. Chen et al. demonstrate the combination of color structured lighting with stereo vision techniques. In particular, a color pattern is projected onto an object and stereo images are captured. Correspondences are derived between the stereo images as opposed to between a captured image and the projected image.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Kevin Siangchin whose telephone number is (703)305-7569. The examiner can normally be reached on 9:00am - 5:30pm, Monday - Friday.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Amelia Au can be reached on (703)308-6604. The fax phone number for the organization where this application or proceeding is assigned is 703-872-9306.

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